

**MONITORING AND STUDIES OF NATIVE FISHES OF THE COLORADO
RIVER ECOSYSTEM IN GRAND CANYON**

INTERIM REPORT

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for

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INTRODUCTION

Our monitoring and research project on native fishes of Grand Canyon was funded by the Grand Canyon Monitoring and Research Center (GCMRC) through a competitive, peer-review process. The primary objectives of the funded work are two-fold. The first is to conduct studies and analyses that address the linkage of dam-controlled flow regimes to the ecology of native fishes in Grand Canyon. Ecological factors listed in the GCMRC's Request for Proposals (RFP) to be considered include: reproductive success, larval transport, recruitment, food resources and diet (RFP Objective 1); predator-prey and competitive interactions between native and non-native species (RFP Objective 3); diseases, parasites and condition factor (RFP Objective 4); available habitats and habitat use in near-shore areas (RFP Objective 5); temperature, physiology, and growth (RFP Objective 6). Additional ecological factors to be considered include ontogenetic changes, temporal activity patterns, movement, spawning, population age structure, and distribution (mainstem vs. tributaries). Our primary objective will be addressed by assembling integrated data sets of distribution of native and non-native fishes in relation to abiotic and biotic factors throughout the Grand Canyon, and by developing life history models for each species from existing data and published works. Linkages among dam operations, flow regimes, abiotic and biotic factors, and the native fish community will be identified using multivariate analyses.

The second primary objective is to monitor the status and trends of native fish populations in Grand Canyon (RFP Objective 2). Continued monitoring is necessary to assess the status of native fishes, especially the endangered humpback chub - particularly in the context of changing dam operations and flow regime. However, because of the limited scope of the present contract, new monitoring efforts must be more focused in detecting trends in native fish populations. Thus, our monitoring focuses on the lower 14 km of the Little Colorado River (LCR) because this is where the endangered humpback chub successfully reproduces, and the mainstem Colorado River inflow reach (river miles 61-68) because this area contains the largest mainstem population. Other areas of focus are other tributaries and adjacent mainstem reaches (Paria, Bright Angel, Shinumo, Kanab, and Havasu), because almost all native fish in Grand Canyon are dependent on these streams for reproduction and early life history stages. Other mainstem areas where aggregations of humpback chub are known to occur, e.g., Fence Fault at river mile 29, and Middle Granite Gorge at river mile 128 are also included in the monitoring program. Whenever

possible, we sample habitats for fish so as to provide critical information on fish populations and their habitat relationships. Our sampling is designed to detect reproductive success, survivorship of young-of-year, and status of adult populations. Non-native fishes are included in our monitoring as these species represent a significant component of the fish community and may be involved in significant interspecific interactions.

Conventional sampling approaches including electrofishing, trammel netting, minnow trapping, and seining will be employed to sample fish in mainstem near-shore habitats (shorelines, eddy complexes, backwaters). New sampling methods applied in mainstem near-shore habitat that we developed for our tributary studies in the early 1990s include mini-hoopnet and point-centered habitat measurements. Our fish and habitat sampling is linked to Dr. Dean Blinn and Joseph Shannon's food base studies and will provide a better understanding of diet and food resources for native fish in Grand Canyon. These new approaches are critical in linking past tributary and mainstem studies and will permit synthesis of more accurate and detailed native and non-native fish life histories. Fish health monitoring is included as a component of our fish sampling to develop a better understanding of the relationship between fish diseases and environmental conditions in Grand Canyon.

Growth experiments are in progress to address the thermal requirements for growth and survivorship of the endangered humpback chub. Swimming performance studies will determine ranges of temperature and flow velocity where juvenile flannemouth sucker and other native fishes are not displaced. This information is needed to identify target mainstem conditions for modification of dam operations (flow regime and thermal warming). These experiments are being conducted at the Willow Beach National Fish Hatchery, where we have constructed a state-of-the-art facility for research on growth, diet, behavior, swimming performance, etc.

Our monitoring and studies will provide information to the Adaptive Management Program for development of conceptual ecosystem models, designing future experimental flows, and identifying information needs for future studies and monitoring. Furthermore, our work will provide critical information for developing management plans and actions aimed at removing

jeopardy to the endangered humpback chub and improving the status of other native fishes in Grand Canyon.

ACTIVITIES FY98

Notification of intent to award the Grand Canyon Fishery Resources Office (GCFRO) the contract for monitoring and research on native fishes in Grand Canyon occurred on 1 October 1997. Following this notification, the Fish and Wildlife Service (FWS), the Bureau of Reclamation (BOR), and the Grand Canyon Monitoring and Research Center (GCMRC) entered into negotiations for reduction of the usual 19% full indirect cost rate to 10%. Negotiations and signatures were completed on 8 April 1998. Field work was initiated on 27 March 1998, prior to finalization of the contract. Over 500 person-days of field work were done during FY1998 during seven separate field trips (Table 1).

Table 1. Schedule of completed field work.

Trip title	Dates	Trip objective
Spring Little Colorado River monitoring and research	27 March-6 May 1998	Fishery research and monitoring
Little Colorado River food base monitoring	5-8 June 1998	Macroinvertebrate, stable isotope studies
Mainstem Colorado River and tributaries monitoring and research	16 June-1 July 1998	Fishery research and monitoring
Little Colorado River monitoring and research	22-31 July 1999	Fishery research and monitoring
Little Colorado River food base monitoring	3-6 August 1998	Macroinvertebrate, stable isotope studies
Mainstem Colorado River and tributaries monitoring and research	26 August-11 September 1998	Fishery research and monitoring
Little Colorado River monitoring, research and food base monitoring	20-24 October 1998	Fishery research and monitoring and macroinvertebrate, stable isotope studies

The process for filling new positions commenced in January 1998 and all positions were filled by 25 June 1998. Cooperative agreements were developed and finalized with Navajo Natural Heritage Program (NNHP) on 11 June, Hualapai Tribe on 3 June, Northern Arizona University (NAU) on 4 June, University of Arizona (UA) on 23 September, and Arizona Game and Fish Department (AGFD) on 1 June.

TRIP AND SUB-PROJECT SUMMARIES

Little Colorado River monitoring and research, spring 1998

Tim Hoffnagle, AGFD

Owen Gorman, USFWS

Trip Objectives

1. Continue historical AGFD spring monitoring activities.
2. Monitor influx of adult humpback chub into the Little Colorado River during the spawning season.
3. Measure habitat use by humpback chub and other fishes at locations of net sets.

Results and Discussion

Fish abundance was monitored in the Little Colorado River (LCR) during four 11-day trips from 27 March - 6 May. Teams from the U. S. Fish and Wildlife Service (USFWS) conducted Trips 1 (27 March - 6 April) and 4 (27 April - 6 May), while teams from the Arizona Game and Fish Department (AGFD) conducted Trips 2 (6 - 17 April) and 3 (17 - 27 April). Trip length varied from 9 - 11 days, due to weather.

Capture of fishes was accomplished using three different standardized gear types: large hoopnets, mini-hoopnets and minnow traps. Sixteen large hoopnets, two minihoopnets and two groups of five minnow traps were set at standard sites in the lower 1.2 km of the Little Colorado River (Robinson and Clarkson 1992; Robinson et al. 1996; Brouder and Hoffnagle 1998a; b). Capture gears were checked twice daily, at dusk and dawn. Water temperature and turbidity were measured in the Little Colorado River at Boulder Camp (2 km from the mouth)

immediately preceding morning gear checks and following evening gear checks. Little Colorado River discharge data were obtained from the USGS gage at Cameron and 235 cfs was added to compensate for base flow from Blue Springs, approximately 48 km downstream from the gage (21 km from the mouth).

Monitoring trips were successful in capturing all species of native and common non-native fishes. However, spring flooding in the Little Colorado River in 1998 was later and lasted longer than usual. Thus, we appear to have missed the spawning run, since catches were not as high as in previous years, and there was a low frequency of fish in spawning condition (Hoffnagle 1998). Fish captured during spring monitoring are summarized in Table 2. Data collected by USFWS and AGFD are currently being merged for further analyses. Catch rates will be compared with those of previous years at these standardized sampling sites. In addition, condition factor and prevalence of *Lernaea cyprinacea* infestation of fishes will be examined, as will temperature, turbidity, and discharge of the Little Colorado River. These factors have been shown to affect fish catch (Robinson and Clarkson 1992; Valdez and Ryel 1995; Arizona Game and Fish Department 1996).

USFWS personnel measured habitat around hoopnets at the start and end of the 40-day monitoring period to provide a sample of changing habitat conditions during the spring spawning season. Additionally, FWS measured stream cross-sections to provide data on changes in habitat as stream discharge dropped from high early spring flows to near-base flows in late spring. Trammel nets were set and run daily near the mouth of the Little Colorado River during the first and last 10-day portions of the monitoring period. Water quality data (temperature, dissolved oxygen, pH, conductivity, salinity) was recorded hourly, and turbidity was recorded daily during the first and last 10-day portions of the 40-day monitoring period.

Table 2. Preliminary summary of fish captured by gear type, lower 1.2 km of the Little Colorado River, 27 March-27 April, 1998.

Gear type	Species ^a											Total
	BBH	BHS	CCF	CCP	FHM	FMS	HBC	PKF	RBT	RSH	SPD	
Hoopnet	1	68	17	4	109	22	268	2	8	18	167	684
Minnow trap	0	1	0	0	2	1	14	0	0	2	5	25
Trammel	0	1	0	2	0	40	5	0	5	0	0	53
Total	1	70	17	6	111	63	287	2	13	20	172	762

^aBBH = black bullhead (*Ameiurus melas*); BHS = bluehead sucker (*Catostomus discobolus*); CCF = channel catfish (*Ictalurus punctatus*); CCP = common carp (*Cypinus carpio*); FHM = fathead minnow (*Pimephales promelas*); FMS = flannelmouth sucker (*Catostomus latipinnis*); GRS = green sunfish (*Lepomis cyanellus*); HBC = humpback chub (*Gila cypha*); RBT = rainbow trout (*Oncorhynchus mykiss*); RSH = red shiner (*Cyprinella lutrensis*); SPD = speckled dace (*Rhinichthys osculus*).

Little Colorado River monitoring and research, July 1998

Robert G. Bramblett

Owen T. Gorman

Trip Objectives

1. Monitor humpback chub and other native and non-native fish in the Little Colorado River.
2. Sample shoreline habitat and use by resident fishes to complement mainstem Colorado River studies.
3. Monitor water quality and log water temperature in a variety of aquatic habitats.
4. Capture young-of-the-year (YOY) humpback chub for experimental studies at Willow Beach National Fish Hatchery.
5. Capture ~ 25 adult speckled dace and transport to Willow Beach National Fish Hatchery for fish health assay.

Results and Discussion

On day three of our trip (24 July) at about 0610 hrs, a large (~ 100 cm) flood entered the Salt Camp reach of the Little Colorado River. The high flows continued for 24 hours before receding, and several smaller spates of 15 – 30 cm occurred throughout the remainder of the trip. The flooding made fishing hoopnets, minnow traps, and seines impracticable, and thereby affected our ability to fully meet our objectives.

Objective 1, monitoring humpback chub and other native and non-native fish, was partially met. We were able to run fishing gear for four days only, rather than the nine days we planned. Additionally, the high flows and turbidity reduced capture efficiency of fishing gear. Despite the poor conditions, we were able to capture 230 fish of 4 native and 5 non-native species (Table 3). Initial conclusions from fish monitoring include documentation of reproduction by humpback chub, speckled dace, flannelmouth sucker, and bluehead sucker, and evident lack of reproduction by common carp, fathead minnow, and red shiner.

Full achievement of Objective 2, measurement of shoreline habitat and habitat use, was similarly limited by the flood. We had planned on measuring habitat at 180 hoopnet and minnow trap sets, and shoreline transects. However, the continued flooding limited our habitat measurements to 46 hoopnets, 34 minnow traps, and 39 shoreline transects.

Objective 3, water quality monitoring, was completed, although the flood probably masked temperature patterns that normally occur during summer base flow conditions. Also, while no thermographs were lost, several had been buried by sediment or swept ashore by the flood.

Objective 4, capture of YOY humpback chub for experimental studies, was achieved. Approximately 34.4 hours of seining effort over two days yielded ~399 YOY humpback chub. On Thursday, 30 July 1998, the humpback chub were transported to Willow Beach National Fish Hatchery by BOR helicopter (Steve Chubbuck, Pilot). The fish arrived in excellent condition; no mortalities occurred during transport.

Flood conditions and extreme turbidity ($> 50,000$ NTU) almost certainly reduced catch rates of YOY humpback chub. Most YOY humpback chub were captured by seining in areas with current velocities near zero, often over a sand substrate and in small pockets of quiet water adjacent to boulders. We speculate that the use of these habitats may be related to the flood conditions. Handling protocol for YOY humpback chub prohibited taking length and weight measurements; however, we estimated the size range of these fish at 35 – 50 mm. Many of the YOY humpback chub captured by seining were smaller than those occurring in our hoopnet and

minnow trap catches; however, mesh size in seines was 3/16" and 1/8", while mesh size in hoopnet and minnow traps was 1/4".

Relative abundance of YOY based on seine catches indicated that humpback chub and bluehead sucker were most common and approximately co-dominant in abundance. Speckled dace were the next most abundant species and flannemouth suckers were rare.

Adult fathead minnows, some probably over two years old (> 65 mm TL) and red shiners, some probably more than one year old (> 65 mm TL) were very common. However, we did not observe any YOY fathead minnows or red shiners. Also missing from seine catches were YOY common carp, although 1+ and 2+ fish were present. This pattern of YOY abundance suggests that native species had a more successful reproductive effort this year than nonnative species.

Objective 5, capture and transport of speckled dace for fish health assay, was completed. The speckled dace were examined by Jerry Landye, USFWS. Asian tapeworms (*Bothriocephalus acheiognathi*) were confirmed in this sample, but no anchor worms (*Lernaea cyprinacea*) were found in any fish sampled.

Table 3. Preliminary summary of fish captured by site gear type, Little Colorado River, 22-31 July 1998.

Gear type	Species ^a									Total
	BHS	CCF	CCP	FHM	FMS	HBC	PKF	SPD	YBH	
Hoopnet	5	5	24	5	1	164	2	10	3	219
Minnow trap	0	0	0	1	0	3	5	2	0	11
Seine ^b	0	0	0	0	0	399	0	0	0	399
Total	5	5	24	6	1	566	7	12	3	629

^aBHS = bluehead sucker (*Catostomus discobolus*); CCF = channel catfish (*Ictalurus punctatus*); CCP = common carp (*Cyprinus carpio*); FHM = fathead minnow (*Pimephales promelas*); FMS = flannemouth sucker (*Catostomus latipinnis*); HBC = humpback chub (*Gila cypha*); PKF = plains killifish (*Fundulus zebrinus*); SPD = speckled dace (*Rhinichthys osculus*); YBH = yellow bullhead (*Ameiurus natalis*).

^bAdditional species captured during seining that were not counted: red shiner (*Cyprinella lutrensis*), yellow bullhead, fathead minnow, bluehead sucker, plains killifish, common carp, speckled dace.

Little Colorado River monitoring and research, October 1998

Robert G. Bramblett
Owen T. Gorman

Trip objectives

1. Monitor humpback chub and other native and non-native fish in the Little Colorado River.
2. Sample shoreline habitat and use by resident fishes to complement mainstem Colorado River studies.
3. Monitor water quality and water temperature.
4. Assist NAU researcher Allen Haden in food base studies.

Results and discussion

This trip was initiated as a partial make-up for the July trip, which was disrupted by flooding. Objective 1, monitoring humpback chub and other native and non-native fish, was met. We captured 214 fish of 3 native and 4 non-native species during four days of sampling (Table 4).

Speckled dace were the most abundant species, followed by humpback chub, fathead minnow, red shiner, common carp, flannelmouth sucker and yellow bullhead. No bluehead suckers were captured, and only one flannelmouth sucker was captured. Only speckled dace and humpback chub were abundant.

Preliminary analysis indicates that we captured 60 humpback chub total, of which 19 (32%) were YOY (65-85 mm, Figure 1). In contrast, during the July 1998 trip, we captured 162 humpback chub total, and 7% of these were YOY. Therefore, YOY humpback chub comprised a larger proportion of the catch in the October than in the July sample. The disparity in proportional catches may be because during July 1998 many YOY humpback chub were too small to be captured in the 1/4" mesh of our hoopnets.

Moreover, seining efforts in July yielded more YOY humpback chub than our seining on this trip. In July, we captured 400 YOY humpback chub in roughly two days of seining with two

crews under turbid water conditions. During the current trip, one crew seining for one day and another crew seining for 1.5 hours failed to capture any YOY humpback chub under blue water conditions. However, the larger size of humpback chub in October, together with the less turbid water conditions, may have reduced the capture efficiency for seining. Alternatively, abundance of YOY humpback chub in the Little Colorado River may have been reduced due to frequent flooding during the summer monsoon season, or in combination with volitional downstream movements. In any event, the presence of some YOY humpback chub during this trip indicates that flooding or volitional movements did not entirely deplete the local population of YOY humpback chub.

Objective 2 was met. We measured available habitat at 41 shoreline transects and at 4 full cross-section transects. Habitat was also measured at 41 hoopnet and 27 minnow trap sets. Objective 3, water quality and temperature monitoring, was completed. Water quality data are summarized in Table 5. Turbidity varied during the trip. Rains occurring 20-22 October caused a localized flow event from Big Canyon located about 700 m upstream from Salt Camp. Although the stage did not rise appreciably, turbidity increased from 10 NTU on 21 October to 45 NTU on 22 October as the water changed from typical blue base-flow color to brown. By 24 October, turbidity had declined to 32 NTU as the water returned to a primarily blue color.

Objective 4 was completed. We assisted Allen Haden in collecting and sorting food base samples from Salt Creek, the Little Colorado River at Salt Camp, and the Little Colorado River at Chute Falls.

Table 4. Preliminary summary of fish captured by gear type, Little Colorado River, 20-24 October 1998.

Gear	Species ^a							Total
	CCP	FHM	FMS	HBC	SPD	RSH	YBH	
Hoopnet	2	8	1	51	94	4	1	161
Minnow trap	0	4	0	5	29	0	0	38
Seine	1	4	0	5	1	4	0	15
Totals	3	16	1	61	124	8	1	214

^aCCP = common carp (*Cyprinus carpio*); FHM = fathead minnow (*Pimephales promelas*); FMS = flannelmouth sucker (*Catostomus latipinnis*); HBC = humpback chub (*Gila cypha*); SPD = speckled dace (*Rhinichthys osculus*); RSH = (*Cyprinella lutrensis*) YBH = yellow bullhead (*Ameiurus natalis*).

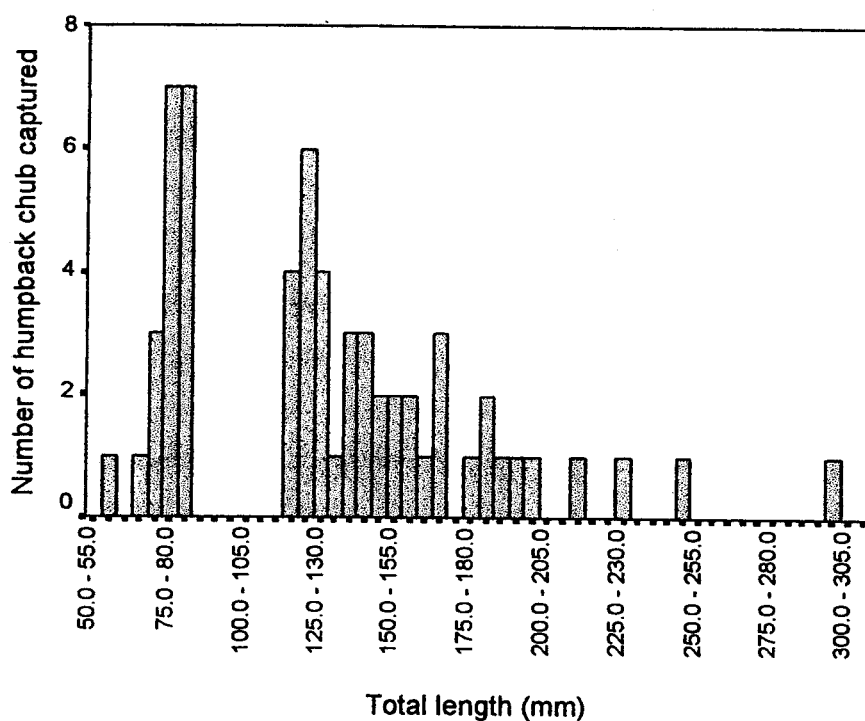


Figure 1. Length-frequency histogram of humpback chub captured at Salt Camp reach, Little Colorado River, 20-24 October, 1998.

Table 5. Summary of water quality data collected in the Little Colorado River at Salt Camp, 20 (1220 hrs)-24 (0640 hrs) October 1998. Temperature, dissolved oxygen, specific conductivity and pH samples were collected at 10 min intervals, $N=542$ readings. Turbidity was measured five times total.

Parameter	Average	Minimum	Maximum
Temperature (°C)	19.6	18.8	20.5
Dissolved oxygen (mg/L)	7.0	6.5	8.0
Specific conductance (microseimens)	4539.7	4431.0	4657.0
PH	7.4	7.3	7.6
Turbidity (NTU)	33	10	45

**Mainstem Colorado River and tributaries monitoring and research,
16 June-1 July 1998 (Trip 1) and
26 August-11 September 1998 (Trip 2)**

Robert G. Bramblett
Owen T. Gorman

Trip Objectives

1. Monitor fish populations at sites in the mainstem Colorado River and tributaries.
2. Sample available habitats and habitats used by fish at mainstem Colorado River sites and tributaries.
3. Conduct a fish health assessment survey for mainstem Colorado River and tributaries.
4. Collect samples for stable isotope analysis as part of native fish food base study.
5. Monitor water quality and temperature at mainstem sites and in tributaries.
6. Conduct survey of shoreline habitats in the mainstem Colorado River under diel fluctuating flow conditions.
7. Conduct a seining survey of backwaters in mainstem habitats.

Study Areas and Methods

Fish populations were monitored with electrofishing, trammel nets, hoopnets, minnow traps, and seining at eight mainstem Colorado River locations (Tables 6-9). During Trip 2, additional sampling was done at in the mainstem at Fence Fault (RM 30.5) and above Tanner Rapids (RM 68). In addition to the primary mainstem sites, backwaters were seined at locations along the mainstem from the vicinity of the Little Colorado River downstream to RM 192 (Tables 8 and 9).

Fish populations were monitored at five tributary sites: Little Colorado River, Bright Angel Creek, Shinumo Creek, Kanab Creek, and Havasu Creek (Tables 6-9). Fish were captured in tributaries using hoopnets, minnow traps, and seining.

Available habitat and habitat used by fish was measured at mainstem Colorado River sites and tributary sites. To assess the effects of fluctuating flow on fish habitat, available habitat was measured along transects at mainstem sites under both low and high flow

conditions during Trip 2. Study reaches for habitat studies were selected based on the habitat classification system of Valdez and Ryel (1995).

Results and Discussion

Effort.-Total length of study reaches was 3040 m for mainstem reaches and 1250 m for tributary confluence sites during Trip 1 and 2880 m for mainstem reaches and 1150 m for tributary confluence sites during Trip 2. During Trip 1, electrofishing was conducted during 11 nights and one morning, trammel nets were set/run on 9 nights and one daytime period. Trapping effort included 179 hoopnet and 192 minnow trap sets with a total effort exceeding 700 trap-days (Table 6). During Trip 2, 34 electrofishing runs were conducted, for 19,788 s of effort. Sixty-one trammel net sets were done, for a total effort of 114.1 hrs. Trapping effort included 229 hoopnet and 282 minnow trap sets, and 96 seine hauls were done (Table 8).

Fish.-During Trip 1, a total of 780 fish of 4 native and 6 nonnative species were captured; 524 fish were captured at mainstem sites and 256 fish were captured at tributary sites. Speckled dace and flannelmouth sucker were the most abundant native species in the catch, followed by humpback chub and bluehead sucker, respectively. Seventy-six humpback chub were captured at 4 of 8 mainstem Colorado River sites and at 4 of 5 tributary sites (Table 7). Catches of native fish species at mainstem sites were lower than catch of non-native species at all mainstem Colorado River sites. In all tributaries, catches of natives were greater than non-native species. At tributary sites, 82% of the fish captured were native species, while at mainstem sites 22% of the fish captured were native species.

Rainbow trout were the most abundant nonnative species captured, as well as the most abundant overall. Brown trout was the next most abundant nonnative species. Catch of brown trout was highest in the mainstem Colorado River near Bright Angel Creek and catch of rainbow trout was highest in mainstem Colorado River near Havasu Creek.

Overall, capture of fish was higher during Trip 2 than Trip 1. During Trip 2, 2,167 fish

of 4 native and 8 nonnative species were captured; 1615 fish were captured at mainstem sites and 552 fish were captured at tributary sites (Table 9). As we observed during Trip 1, native species comprised more of the fish community at tributary sites than at mainstem sites. At tributary sites, 92.0% of the fish captured were native species, while at mainstem sites 48.6 % of the fish captured were native species.

During Trip 2, speckled dace (*Rhinichthys osculus*) were the most abundant native species, followed by humpback chub (*Gila cypha*), flannelmouth sucker (*Catostomus latipinnis*), and bluehead sucker (*Catostomus discobolus*), respectively. A total of 390 humpback were captured at 8 of 10 mainstem Colorado River sites and at 4 of 5 tributary sites (Table 9).

Rainbow trout (*Oncorhynchus mykiss*) was the most abundant nonnative species, followed by fathead minnow (*Pimephales promelas*), brown trout (*Salmo trutta*), red shiner (*Cyprinella lutrensis*), common carp (*Cypinius carpio*), plains killifish (*Fundulus zebrinus*), channel catfish (*Ictalurus punctatus*) and yellow bullhead (*Ameiurus natalis*), respectively.

Stage fluctuations.-During both trips, daily stage fluctuations ranging from 48–100 cm were measured at mainstem Colorado River sites. This diel stage fluctuation appeared to lower the utility of backwaters and vegetated shorelines as fish habitat and macroinvertebrate production areas. During daily low flows, backwaters were largely dewatered and available cover for juvenile fish was diminished along vegetated shorelines as water levels dropped below the vegetation.

Cooperative food base studies with Dr. Blinn/NAU were addressed by collection of fish tissue samples from mainstem Colorado River and tributary sites for stable isotope analysis. Water quality parameters including temperature, dissolved oxygen, conductivity, pH, turbidity and Secchi depth were monitored at all sampling sites.

Fish health assessment -During Trip 1, fish health samples were taken from 116 fish collected between Lee's Ferry and Diamond Creek. Species examined included speckled dace, humpback chub, rainbow trout, fathead minnow, bluehead sucker and plains killifish. Asian tapeworms (*Bothriocephalus acheilognathi*) were confirmed from fish collected from the Little Colorado River, but no anchorworm (*Lernaea cyprinacea*) were found in any fish examined. High numbers of Costia (*Ichthyobodo*) were found on moribund and trapped fish from Kanab Creek. The high infection level of Costia observed in Kanab fish may well contribute to increased summer mortality as water temperature increases and dissolved oxygen level decreases.

During Trip 2, fish health samples were collected from 122 speckled dace from Bright Angel, Shinumo, Kanab, and Havasu creeks. All fish were preserved in 10% formalin, except 35 live speckled dace from Havasu Creek that were delivered to Jerry Landye, who met us at Diamond Creek. Due to flash flooding, Diamond Creek was not sampled.

No anchor worms (*Lernaea cyprinacea*) were seen on any speckled dace. Asian tapeworms were observed in 8 of 39 fish from Kanab Creek. A nematode was found in the intestinal tracts of 3 of 25 speckled dace from Shinumo Creek, 16 of 35 dace from Havasu Creek and not observed in samples from Kanab and Bright Angel creeks. White grubs (*Posthodiplostomum* spp.) were found in the mesenteries of 4 of 39 speckled dace from Kanab Creek and 4 of 35 dace from Havasu Creek. During the external exam of the moribund dace from Havasu Creek, light infections of *Gyrodactylus* were present on skin and gills, and *Chilodonella* were observed on the gills. Viral and bacterial analysis from samples taken from Havasu Creek are being processed at the Pinetop FHC.

Table 6. Preliminary summary of habitat sampled at transects and gear fished by site, Colorado River and tributaries, 16-30 June 1998.

Site/river mile	Dates	Habitat measured and gear fished				Trammel netting
		Length of transect (m)	Hoopnets	Minnow traps	Electrofishing	
<i>Mainstem Sites</i>						
Mainstem @ Little Colorado/61	16-18 June	600	29	24	4 nights, 1 morning ^a	3 nights
Hopi Salt/63.5	18-20 June	600	30	30	4 nights, 1 morning ^a	
Lava Chuar/65.2	20-22 June	600	28	30	4 nights, 1 morning ^a	
Mainstem @ Bright Angel/87.7	23-24 June	600	16	16	1 night	1 night
Mainstem @ Shinumo /108.7	24 June	N/A	N/A	N/A	1 night	1 night
Mainstem @ Middle Granite Gorge/126	25-27 June	300	17	24	2 nights	2 nights
Mainstem @ Kanab Creek/143.5	27 June	N/A	N/A	N/A	1 night	1 night
Mainstem @ Havasu/156.8	28-30 June	340	5	9	2 nights	1 night
<i>Tributary Sites</i>						
Little Colorado/61.4	16-18 June	N/A	0	8	N/A	4 sets
Bright Angel Creek/87.8	22-24 June	~430	10	23	N/A	N/A
Shinumo Creek/108.7	24-25 June	~120	14	16	N/A	N/A
Kanab Creek/143.5	27-28 June	500	14	13	N/A	N/A
Havasui Creek/156.8	28-30 June	200	16	19	N/A	1 set

^a 17 electrofishing efforts were done from RM 60.1-65.1 during 6/17/98-6/21/98

Table 7. Preliminary summary of fish captured by site and gear type, Colorado River and tributaries, 16-30 June 1998.

Site	Gear	Species ^a										Totals
		BHS	BRT	CCP	FHM	FMS	GRS	HBC	RBT	RSH	SPD	
<i>Mainstem Sites</i>												
Mainstem	Electrofish	0	1	1	0	0	0	2	74	0	0	44
@ Little	Trammel	1	0	0	0	9	0	8	7	0	0	27
Colorado	Hoopnet	0	0	0	0	1	0	11	4	0	0	16
17-21	Minnow trap	0	0	0	1	0	0	0	0	0	0	1
June												
1998	Totals	1	1	1	1	10	0	21	85	0	0	119
Hopi Salt	Electrofish	0	1	1	0	2	0	2	35	0	0	41
18-21	Hoopnet	0	0	0	0	0	0	2	4	0	1	7
June 1998	Dip net	0	0	0	0	0	0	1	0	0	0	1
	Minnow trap	0	0	0	2	0	0	4	0	0	4	10
	Totals	0	1	1	2	2	0	9	39	0	5	59
Lava	Electrofish	0	0	0	19	0	0	14	23	1	5	62
Chuar	Hoopnet	0	0	0	3	0	0	1	5	0	3	12
Mainstem	Minnow trap	0	0	0	1	0	0	3	0	0	3	7
21-22	Totals	0	0	0	23	0	0	18	28	1	11	81
June 1998												
Mainstem	Electrofish	0	30	0	0	2	0	0	11	0	0	43
@ Bright	Minnow trap	0	0	0	0	0	0	0	0	0	3	3
Angel	Hoopnet	0	0	0	2	0	0	0	0	0	0	2
22-24	Trammel	1	9	0	0	0	0	0	4	0	0	13
June 1998	Totals	1	39	0	2	2	0	0	15	0	3	61
Mainstem	Electrofish	0	12	2	1	2	0	0	26	1	0	44
@	Trammel	0	0	0	0	0	0	0	2	0	0	2
Shinumo	Totals	0	12	2	1	2	0	0	28	1	0	46
24 June												
1998												
Mainstem	Electrofish	0	5	0	0	1	0	5	24	0	0	35
@ Middle	Hand	0	0	0	0	0	0	1	0	0	0	1
Granite	Minnow trap	0	0	0	0	0	0	0	1	0	0	1
25-27	Hoopnet	0	1	0	0	0	0	3	0	1	0	5
June 1998	Trammel	0	0	0	0	0	0	0	1	0	0	1
	Totals	0	6	0	0	1	0	9	26	1	0	43
Mainstem	Electrofish	0	0	2	1	2	0	0	10	0	0	15
@ Kanab	Trammel	0	0	1	0	2	0	0	1	0	0	4
Creek	Totals	0	0	3	1	4	0	0	11	0	0	19
27 June												
1998												

Table 7. Continued.

Site	Gear	Species										Totals
		BHS	BRT	CCP	FHM	FMS	GRS	HBC	RBT	RSH	SPD	
Mainstem @ Havasu Creek 28-29 June 1998	Electrofishing	2	3	6	0	8	1	0	70	0	2	90
	Minnow trap	0	0	0	0	0	0	0	0	0	4	4
	Hoopnet	0	0	0	0	0	0	0	2	0	0	2
	Totals	2	3	6	0	8	1	0	72	0	6	96
	Mainstem subtotals	4	61	12	30	29	1	57	274	3	25	524
<i>Tributary Sites</i>												
Little Colorado 17-21 June 1998	Minnow trap	0	0	0	0	0	0	11	0	1	12	24
	Seine	0	0	0	1	0	0	0	0	26	1	28
	Trammel	0	0	4	0	11	0	8	0	0	0	23
	Totals	0	0	4	1	11	0	19	0	27	13	75
Bright Angel Creek 23-24 June 1998	Minnow trap	1	0	0	0	0	0	0	1	0	46	48
	Hoopnet	0	2	0	0	0	0	0	0	0	4	6
	Totals	1	2	0	0	0	0	0	1	0	50	54
Shinumo Creek 25 June 1998	Hoopnet	7	5	0	0	2	0	1	0	0	4	19
	Totals	7	5	0	0	2	0	1	0	0	4	19
Kanab Creek 28 June 1998	Minnow trap	0	0	0	3	2	0	0	0	0	3	8
	Hoopnet	0	0	0	2	8	2	1	0	0	5	18
	Totals	0	0	0	5	10	2	1	0	0	8	26
Havasu Creek 29-30 June 1998	Minnow trap	0	0	0	0	1	0	0	0	0	6	7
	Hoopnet	5	0	0	0	31	0	6	0	0	4	46
	Trammel	0	0	0	0	26	0	3	0	0	0	29
	Totals	5	0	0	0	58	0	9	0	0	10	82
	Tributary subtotals	13	7	4	6	81	2	30	1	27	85	256
Grand Totals		17	68	16	36	110	3	87	275	33	110	780

*BHS = bluehead sucker (*Catostomus discobolus*); BRT = brown trout (*Salmo trutta*); CCP = common carp (*Cyprinus carpio*); FHM = fathead minnow (*Pimephales promelas*); FMS = flannelmouth sucker (*Catostomus latipinnis*); GRS = green sunfish (*Lepomis cyanellus*); HBC = humpback chub (*Gila cypha*); RBT = rainbow trout (*Oncorhynchus mykiss*); RSH = red shiner (*Cyprinella lutrensis*); SPD = speckled dace (*Rhinichthys osculus*).

Table 8. Preliminary summary of habitat sampled at transects and gear fished by site, Colorado River and tributaries, 27 August – 9 September 1998.

Site/river mile	Dates	Length of study reach (m)	Hoopnets	Minnow traps	Electrofishing efforts (s)	Trammel net sets (hr)	Seining efforts
Mainstem sites							
Fence Fault/30.5	27 August	N/A	N/A	N/A	1 (218)	2 (4.6)	N/A
Mainstem @ Little Colorado/61	28-31 August	300	16	16	6 (3548)	12 (25.1)	3
Hopi Salt/63.5	29-31 August	600	30	30	8 (4479)	4 (6.24)	3
Lava Chuar/65.2	31 August-1 September	580	29	29	N/A	4 (6.75)	N/A
Tanner Rapids/68	1-3 September	560	30	50	4 (2124)	12 (23.2)	1
Mainstem @ Bright Angel/87.7	3-4 September	200	18	18	4 (1668)	6 (12.4)	N/A
Mainstem @ Shinumo /108.7	4 September	N/A	N/A	N/A	2 (1550)	9 (15.6)	N/A
Mainstem above Middle Granite Gorge/ 119-122.8	5 September	N/A	N/A	N/A	N/A	N/A	3
Mainstem @ Middle Granite Gorge/126	4-7 September	340	18	43	4 (1784)	8 (14)	17
Mainstem @ Kanab Creek/143.5	7-8 September	N/A	N/A	N/A	2 (1894)	3 (5.7)	N/A
Mainstem @ Havasu/156.8	8-9 September	300	16	16	3 (2523)	N/A	N/A

Table 8. Continued.

Site/river mile	Dates	Length of study reach (m)	Hoopnets	Minnow traps	Electrofish efforts (s)	Trammel net sets (hr)	Seining efforts
Mainstem below Havasup/157- 179	10 September	N/A	N/A	N/A	N/A	N/A	4
Mainstem below Lava Falls/180- 198.2	10 September	N/A	N/A	N/A	N/A	N/A	9
Tributary Sites							
Little Colorado/61.4	28-31 August	~160	9	9	N/A	N/A	2
Bright Angel Creek/87.8	4 September	~120	11	12			16
Shinumo Creek/108.7	5 September	~120	13	12	N/A	N/A	7
Kanab Creek/143.5	7-8 September	500	19	27	N/A	N/A	13
Havasup Creek/156.8	8-10 September	200	20	20		1 (0.5)	18

Table 9. Preliminary summary of fish captured by site and gear type, Colorado River and tributaries, 27 August – 9 September 1998.

Site, date	Gear	Species ^a												Total
		BHS	BRT	CCF	CCP	FHM	FMS	HBC	PKF	RBT	RSH	SPD	YBH	
		<i>Mainstem sites</i>												
Fence Fault, 27 August 1998	Electrofish	0	0	0	0	0	0	0	0	4	0	0	0	4
	Trammel nets	0	0	0	0	0	3	4	0	27	0	0	0	34
	Totals	0	0	0	0	0	3	4	0	31	0	0	0	38
Little Colorado River, 28-31 August 1998	Electrofish	0	0	0	1	3	5	0	0	61	0	6	0	76
	Hoopnets	0	0	0	0	0	0	1	0	5	0	0	0	6
	Seine	0	0	0	0	5	0	26	0	4	1	16	1	53
	Trammel nets	2	0	0	2	0	11	28	0	37	0	0	0	80
	Totals	2	0	0	3	8	16	55	0	107	1	22	1	215
Hopi Salt, 29-31 August 1998	Electrofish	0	1	1	0	13	0	33	0	12	6	10	0	76
	Hoopnets	2	0	0	0	0	0	31	0	2	0	0	0	35
	Minnow traps	0	0	0	0	0	0	8	0	0	0	0	0	8
	Totals	2	1	1	0	13	0	72	0	14	6	10	0	119
Lava Chuar, 31 August-1 September 1998	Hoopnets	1	0	0	2	1	0	27	0	43	0	0	0	74
	Minnow traps	1	0	0	0	6	0	24	0	0	1	0	0	32
	Trammel nets	0	0	0	0	0	0	6	0	9	0	0	0	15
	Totals	2	0	0	2	7	0	57	0	52	1	0	0	121
Tanner, 1-3 September 1998	Electrofish	0	0	0	0	5	0	19	0	13	2	9	0	48
	Hoopnets	2	0	0	0	5	0	12	0	37	0	0	0	56
	Minnow traps	0	0	0	0	13	0	18	1	3	2	0	0	37
	Seine	2	0	0	0	18	0	22	0	0	13	9	0	64
	Trammel nets	0	1	0	0	0	1	3	0	36	0	0	0	41
	Totals	4	1	0	0	41	1	74	1	89	17	18	0	246
Bright Angel Creek, 3-4 September 1998	Electrofish	1	44	0	0	4	0	0	0	17	1	4	0	71
	Hoopnets	0	1	0	0	1	0	0	0	7	1	0	0	10
	Minnow traps	0	0	0	0	1	0	0	0	0	0	0	0	1
	Trammel nets	0	2	0	0	0	2	0	0	26	0	0	0	30
	Totals	1	47	0	0	6	2	0	0	50	2	4	0	112
Shinumo Creek, 4 September 1998	Electrofish	0	15	0	1	0	0	0	0	25	0	0	0	41
	Trammel nets	1	0	0	1	0	8	11	0	14	0	0	0	35
	Totals	1	15	0	2	0	8	11	0	39	0	0	0	76
Above Middle Granite Gorge, 5 September 1998	Seine	2	0	0	0	2	3	1	3	0	1	67	0	79

Table 9. Continued.

Site, date	Gear	Species ^a												Total
		BHS	BRT	CCF	CCP	FHM	FMS	HBC	PKF	RBT	RSH	SPD	YBH	
Middle Granite Gorge, 4-7 September 1998	Electrofishing	1	0	0	0	2	0	0	0	7	0	0	0	10
	Hoopnets	1	0	0	0	0	0	14	0	2	0	0	0	17
	Minnow traps	0	0	0	0	0	0	2	0	0	0	0	0	2
	Seine	5	0	0	0	0	2	1	0	2	3	4	0	17
	Trammel nets	0	0	0	1	0	0	4	0	17	0	0	0	22
	Totals	7	0	0	1	2	2	21	0	28	3	4	0	68
Kanab Creek, 7-8 September 1998	Electrofishing	0	2	0	2	6	0	1	0	8	0	1	0	20
	Trammel nets	0	0	0	3	0	10	0	0	0	0	0	0	13
	Totals	0	2	0	5	6	10	1	0	8	0	1	0	33
Havasas Creek, 8-9 September 1998	Electrofishing	0	3	0	1	1	0	0	0	15	0	9	0	29
	Hoopnets	1	0	0	1	0	0	0	0	5	0	1	0	8
	Minnow traps	0	0	0	0	0	0	0	0	0	0	1	0	1
	Totals	1	3	0	2	1	0	0	0	20	0	11	0	38
Below Havasas Creek ^b , 10 September 1998	Seine	0	1	0	0	53	18	0	2	19	1	65	0	159
Below Lava Falls ^c , 10 September 1998	Seine	15	0	0	3	92	21	2	2	4	8	164	0	311
	Mainstem subtotals	37	70	1	18	231	87	298	8	463	40	371	1	1625
<i>Tributary sites</i>														
Little Colorado River, 28-31 August 1998	Hoopnets	0	0	0	3	0	0	17	0	0	0	1	0	21
	Minnow traps	0	0	0	0	0	0	4	0	0	0	0	0	4
	Seine	0	0	0	0	1	0	30	6	0	2	3	0	42
	Totals	0	0	0	3	1	0	51	6	0	2	4	0	67
Bright Angel Creek, 4 September 1998	Hoopnets	5	1	0	0	0	1	1	0	3	0	15	0	26
	Minnow traps	0	0	0	0	0	0	0	0	0	0	28	0	28
	Seine	1	0	0	0	0	0	0	0	0	0	18	0	19
	Totals	6	1	0	0	0	1	1	0	3	0	61	0	73
Shinumo Creek, 5 September 1998	Hoopnets	6	1	0	0	1	1	15	0	2	0	19	0	45
	Minnow traps	0	0	0	0	1	2	7	0	0	1	7	0	18
	Seine	0	0	0	0	1	1	0	0	1	0	28	0	31
	Totals	6	1	0	0	3	4	22	0	3	1	54	0	94
Kanab Creek, 7-8 September 1998	Hoopnets	12	0	0	6	4	9	0	0	1	0	30	0	62
	Minnow traps	3	0	0	0	3	3	0	0	0	0	7	0	16
	Seine	23	0	0	0	0	0	0	0	0	0	50	0	73
	Totals	38	0	0	6	7	12	0	0	1	0	87	0	151

Table 9. Continued.

Site, date	Gear	Species ^a												Total
		BHS	BRT	CCF	CCP	FHM	FMS	HBC	PKF	RBT	RSH	SPD	YBH	
Havas Creek, 8-10 September 1998	Hoopnets	17	0	0	0	2	24	17	0	2	0	16	0	78
	Minnow traps	7	0	0	0	2	10	0	0	0	0	40	0	59
	Seine	7	0	0	0	0	0	0	0	0	0	17	0	24
	Trammel nets	0	0	0	0	0	5	1	0	0	0	0	0	6
	Totals	31	0	0	0	4	39	18	0	2	0	73	0	167
	Tributary subtotals	81	2	0	9	15	56	92	6	9	3	279	0	552
	Grand Total	118	72	1	27	246	143	390	14	472	43	650	1	2177

^aBHS = bluehead sucker (*Catostomus discobolus*); BRT = brown trout (*Salmo trutta*); CCP = common carp (*Cyprinus carpio*); FHM = fathead minnow (*Pimephales promelas*); FMS = flannelmouth sucker (*Catostomus latipinnis*); GRS = green sunfish (*Lepomis cyanellus*); HBC = humpback chub (*Gila cypha*); RBT = rainbow trout (*Oncorhynchus mykiss*); RSH = red shiner (*Cyprinella lutrensis*); SPD = speckled dace (*Rhinichthys osculus*); YBH = (*Ameiurus natalis*).

^bBackwaters were seined at RM 165.0L, 165.5L, 165.7L, 166.0R.

^cBackwaters were seined at RM 180.7L, 182.4R, 182.7R, 182.8R, 186.2R, 186.7R, 186.8R, 191.3L, 192.1R, 198.2R.

Table 10. Summary of all fish captured by site and date during 1998, Colorado River and tributaries in Grand Canyon.

Site/River mile	Dates	Species														Totals
		BBH	BHS	BRT	CCF	CCP	FHM	FMS	GRS	HBC	PKF	RBT	RSH	SPD	YBH	
		Mainstem sites														
Fence Fault/30.5	27 August	0	0	0	0	0	0	3	0	4	0	31	0	0	0	38
Little Colorado/61	16-18 June	0	1	1	0	1	1	10	0	21	0	85	0	0	0	120
Little Colorado/61	28-31 August	0	2	0	0	3	8	16	0	55	0	107	1	22	1	215
Hopi Salt/63.5	18-20 June	0	0	1	0	1	2	2	0	9	0	39	0	5	0	59
Hopi Salt/63.5	29-31 August	0	2	1	1	0	13	0	0	72	0	14	6	10	0	119
Lava Chuar/65.2	20-22 June	0	0	0	0	0	23	0	0	18	0	28	1	11	0	81
Lava Chuar/65.2	31 August-1 September	0	2	0	0	2	7	0	0	57	0	52	1	0	0	121
Tanner/68	1-3 September	0	4	1	0	0	41	1	0	74	1	89	17	18	0	246
Bright Angel/87.7	23-24 June	0	1	39	0	0	2	2	0	0	0	15	0	3	0	62
Bright Angel/87.7	3-4 September	0	1	47	0	0	6	2	0	0	0	50	2	4	0	112
Shinumo/10 8.7	24 June	0	0	12	0	2	1	2	0	0	0	28	1	0	0	46
Shinumo/10 8.7	4 September	0	1	15	0	2	0	8	0	11	0	39	0	0	0	76
Above MGG/119- 122.8	5 September	0	2	0	0	0	2	3	0	1	3	0	1	67	0	79
Middle Granite Gorge/126	25-27 June	0	0	6	0	0	0	1	0	9	0	26	1	0	0	43
Middle Granite Gorge/126	4-7 September	0	7	0	0	1	2	2	0	21	0	28	3	4	0	68

Table 10. Continued.

Site/River mile	Dates	Species														Totals
		BBH	BHS	BRT	CCF	CCP	FHM	FMS	GRS	HBC	PKF	RBT	RSH	SPD	YBH	
Kanab/143.5	27 June	0	0	0	0	3	1	4	0	0	0	11	0	0	0	19
Kanab/143.5	7-8 September	0	0	2	0	5	6	10	0	1	0	8	0	1	0	33
Havasui/156.8	28-30 June	0	2	3	0	6	0	8	1	0	0	72	0	6	0	98
Havasui/156.8	8-9 September	0	1	3	0	2	1	0	0	0	0	20	0	11	0	38
Below Havasui/157-179	10 September	0	0	1	0	0	53	18	0	0	2	19	1	65	0	159
Below Lava/180-198.2	10 September	0	15	0	0	3	92	21	0	2	2	4	8	164	0	311
Mainstem totals		0	41	132	1	31	261	113	1	355	8	765	43	391	1	2143
<i>Tributary sites</i>																
Little Colorado/61	16-18 June	0	0	0	0	4	1	11	0	19	0	0	27	13	0	75
Little Colorado/61	28-31 August	0	0	0	0	3	1	0	0	51	6	0	2	4	0	67
Bright Angel/87.7	22-24 June	0	1	2	0	0	0	0	0	0	0	1	0	50	0	54
Bright Angel/87.7	5 September	0	6	1	0	0	0	1	0	1	0	3	0	61	0	73
Shinumo/10 8.7	24-25 June	0	7	5	0	0	0	2	0	1	0	0	0	4	0	19
Shinumo/10 8.7	5 September	0	6	1	0	0	3	4	0	22	0	3	1	54	0	94
Kanab/143.5	27-28 June	0	0	0	0	0	5	10	2	1	0	0	0	8	0	26
Kanab/143.5	7-8 September	0	38	0	0	6	7	12	0	0	0	1	0	87	0	151

Table 10. Continued.

Site/River mile	Dates	Species														Totals
		BBH	BHS	BRT	CCF	CCP	FHM	FMS	GRS	HBC	PKF	RBT	RSH	SPD	YBH	
Havasu/157	28-30 June	0	5	0	0	0	0	58	0	9	0	0	0	10	0	82
Havasu/157	28-31 August	0	31	0	0	0	4	39	0	18	0	2	0	73	0	167
Tributary totals		0	94	9	0	13	21	137	2	122	6	10	30	364	0	808
Little Colorado River																
Little Colorado confluence area	27 March-27 April	1	70	0	17	6	111	350	0	0	2	13	20	172	0	762
Little Colorado@ Salt Camp	22-31 July	0	5	0	5	24	6	1	0	566	7	0	0	12	3	629
Little Colorado@ Salt Camp	20-24 October	0	0	0	0	3	16	1	0	61	0	0	8	124	1	214
Little Colorado totals		1	75	0	22	33	133	352	0	627	9	13	28	308	4	1605
Grand Totals		1	210	141	23	77	415	602	3	1104	23	788	101	1063	5	4556

^a BBH = black bullhead (*Ameiurus melas*); BHS = bluehead sucker (*Catostomus discobolus*); BRT = brown trout (*Salmo trutta*); CCF = (*Ictalurus punctatus*); CCP = common carp (*Cypinus carpio*); FHM = fathead minnow (*Pimephales promelas*); FMS = flannelmouth sucker (*Catostomus latipinnis*); GRS = green sunfish (*Lepomis cyanellus*); HBC = humpback chub (*Gila cypha*); PKF = (*Fundulus zebrinus*); RBT = rainbow trout (*Oncorhynchus mykiss*); RSH = red shiner (*Cyprinella lutrensis*); SPD = speckled dace (*Rhinichthys osculus*); YBH = (*Ameiurus natalis*).

Activities at Willow Beach National Fish Hatchery Owen T. Gorman

Construction of a laboratory facility at Willow Beach National Fish Hatchery (WBNFH) to conduct experimental growth and swimming performance studies commenced on 15 December 1997. An 800 square foot facility was completed by 1 July 1998 and operational by 9 October 1998. On 5 May 1998, 48 humpback chub were transported via helicopter to WBNFH to constitute a broodstock to produce fish for experimental studies. These fish arrived in excellent health, but unfortunately hatchery staff was unable to maintain the stock and it was depleted by 5 July. An experimental stock of ~400 wild young-of-the-year YOY humpback chub (30-40 mm TL) were transported via helicopter from the Little Colorado River to the hatchery on 30 July 1998. Prior to transport, handling protocols for maintaining fish in the hatchery were revised. With the exception of a small loss of fish due to incorrect administration of an antiseptic agent,

most of these fish have thrived at the hatchery. These YOY fish are being used to conduct temperature-growth studies during FY99.

Summary of Fish Health and Parasitology Studies

Tim Hoffnagle, AGFD

Jerry Landye, USFWS

Section 1. AGFD.-Young-of-the-year humpback chub obtained during the August-September mainstem monitoring and research trip were examined for parasite infection, abdominal fat, and condition factor (K) as a measure of health during the fall research trip, as has been done as part of monitoring of the humpback chub population in Grand Canyon since 1996 (Hoffnagle et al. 1998a; b). Abdominal fat was measured using a scale modified from Goede (1993), where percentage of the internal organs covered by fat is estimated: 0 = 0%; 1 = 1-25%; 2 = 26-50%; 3 = 51-75%; 4 = 76-100%. Fish were examined for the presence of two species of parasites: the external parasite *Lernaea cyprinacea* (Copepoda) and the gastrointestinal parasite *Bothriocephalus acheilognathi* (Cestoda). These parasites have been shown to infect humpback chub more than other species and are contracted in the LCR (Brouder and Hoffnagle 1997; Hoffnagle and Cole 1998). Nineteen fish from the Little Colorado River and 16 from the Colorado River were examined.

Little Colorado River fish were a mean of 56.2 mm total length and weighed 1.09 g. They ranged in total length from 51-63 mm and in weight from 0.8-1.5 g. Mean K was 0.61 and K ranged from 0.54-0.68. Abdominal fat score in these fish ranged from 0-1 (0-25% coverage), with 13 (68.4%) having no visible abdominal fat. Only one humpback chub was infested with *Lernaea* and that fish harbored only one individual parasite. *B. acheilognathi* were found in six fish (31.6%).

In the Colorado River, mean fish length was 61.75 mm and ranged from 41-87 mm - one fish was 129 mm. Mean weight was 6.12 g and ranged from 1.7-18.0 g; however, failure of the scale meant that only 5 of 6 fish were weighed. Mean K was 0.80 and ranged from 0.75-0.84. Mean abdominal fat score was 1.75 and scores ranged from 1-3 (1-75% coverage): 43.8% (7) had fat scores of 1; 37.5% (6) scored 2; 18.8% (3) had a score of 3. No humpback chub from the

Colorado River were infested with *Lernaea* and two fish (12.5%) were infected with *B. acheilognathi*.

These results are similar to those reported previously by Brouder and Hoffnagle (1997), Clarkson et al (1997), Hoffnagle and Cole (1998) and Hoffnagle et al (1998a; b). In general, humpback chub from the mainstem Colorado River are healthier (i.e., higher K, more body fat and less parasites) than those from the LCR. This year, however, *Lernaea* prevalence was lower than in previous years, with only one of 35 fish being infected. In comparison, in 1997, 37.5% and 6.7% of the LCR and Colorado River fish, respectively, were infested. I speculate that the low infestation rate in 1998 is due to hydrographic conditions in the Little Colorado River. There was a prolonged spring flood and an early monsoon-flooding season, which may have limited the available time for *Lernaea* to complete its life cycle. *B. acheilognathi* infection rate was also lower (78.6% and 50% in 1996 and 1997, respectively) and may also reflect the protracted flooding and associated cooler water temperatures.

Section 2, USFWS.-During mainstem monitoring and research trips in June and August-September, 1998, fish health samples were obtained from 238 individual fish in the Colorado River and its tributaries from the Little Colorado River downstream to Diamond Creek, Arizona. Speckled dace were targeted as surrogate species for the endangered humpback chub for this study. Thus, speckled dace comprised 93% of the collections made, while flannelmouth suckers, bluehead sucker, fathead minnow, plains killifish, rainbow trout and humpback chub comprised the remaining 7% fish sampled. Non-lethal fish health samples were taken from four chubs; one moribund chub was sacrificed for a complete set of viral, bacterial, and parasitic samples. Most fish were obtained from the Little Colorado River, Bright Angel, Shinumo, Havasu, and Diamond creeks, but some came from shoreline areas along the Colorado River.

No anchor worms, *Lernaea cyprinacea*, were found in any fish sampled, but anchor worms were observed during fish monitoring activities at the confluence of Kanab Creek and the Colorado River. Asian tapeworms (*Bothriocephalus acheilognathi*) were found in speckled dace and fathead minnow specimens from the Little Colorado River and in speckled dace specimens from Kanab Creek. Number of tapeworms per fish ranged from two to six in Little Colorado River

specimens and one to two tapeworms from Kanab Creek speckled dace specimens. Infection rate from speckled dace from the Little Colorado River was 27%, while Kanab Creek was 21%.

High numbers of *Ichthyobodo* (*Costia*) were found on moribund and captured fish from Kanab Creek. In hatchery situations, this level of infection is normally considered basis for treatment to prevent mortality. This parasite was found only in Kanab Creek. Other parasites found in the study area include the protozoan *Trichodina* and the trematodes *Gyrodactylus* and *Posthodiplostomum*.

Although no viral agents have been detected in any samples obtained, several different types of bacteria were found. They include motile *Aeromonas*, *Pseudomonas*, *Staphylococcus*, and *Shigella*. Other gram positive rod-type bacteria were present, but were not specifically identified. None of these bacteria were U.S. Fish & Wildlife Service fish health policy listed bacteria, however, under certain conditions could cause epizootic infections.

While care was taken to obtain the bacterial samples from kidney tissue only, the small size of the fish made this task difficult. Some bacterial contamination of these samples could have occurred from contact with other fish tissues.

Due to logistic constraints, the Paria River has not been sampled. Plans are being made to collect fish health samples from this stream in the future.

Another portion of the study is to review existing gray and published literature. While most of the study thus far has focused on field collections, gray literature has been reviewed from such agencies as U.S. Fish & Wildlife Service, U.S. Bureau of Reclamation, Arizona Game & Fish Dept., Museum of Northern Arizona, and consulting groups such as Bio/West Inc. and S. W. Carothers & Associates, Inc. Also, many journals have been reviewed and pertinent articles were noted. Literature searches and summaries will be continued during the winter.

Little Colorado River Food Base and Stable Isotope Analysis

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Introduction

The Little Colorado River is critical habitat for the continued existence of the endangered cyprinid, humpback chub in the Grand Canyon (U. S. Fish and Wildlife Service 1994). The Little Colorado River and the mainstem around the confluence is the site of the largest aggregation of humpback chub below Glen Canyon Dam. The importance of the Little Colorado River to the life history of these fishes in the Grand Canyon is two-fold. One, it is the location of a resident population of humpback chub (Douglas and Marsh 1996); two, it provides important warm water spawning habitat (Kaeding and Zimmerman 1983, Gorman and Stone in press, Douglas and Marsh 1996), not found in the mainstem due to the metalimnetic releases from Glen Canyon Dam. Adult humpback chub from the mainstem Colorado River migrate into the Little Colorado River to spawn and move out again after spawning (Douglas and Marsh 1996, Valdez and Ryel 1995). Spawning success is thought to be low in the mainstem Colorado River and humpback chub that drift into the mainstem from the Little Colorado River may have low survival due to thermal shock (Kaeding and Zimmerman 1983, Lupher and Clarkson 1994). The fate of YOY humpback chub that survive drifting into the mainstem is unclear. Cold temperatures may limit growth and cause thermal shock, which may contribute to high losses to predation (Lupher and Clarkson 1994, Valdez and Ryel 1995). Food may also be a factor contributing to the survival of these fish. Little is known about the diet of sub-adult humpback chub in either the mainstem or the Little Colorado River. Kubley and Cole (1979) speculated that food might be limited in the Little Colorado River because of high travertine deposition. Valdez and Ryel (1995) showed that adult humpback chub from the mainstem Colorado River fed on the amphipod *Gammarus lacustris*, simuliids, and chironomids as well as terrestrial insects. They also speculated that because sub-adult humpback chub use shoreline talus, boulders and vegetation rather than mid channel habitats food could be limiting to these size classes in the mainstem. The dependence on terrestrial insects is confusing since numbers of terrestrial insects in drift samples from the mainstem are low (Shannon et al. 1996). The diet of the smaller size classes of humpback chub is important to understanding the ecological

limitations of these fish. No studies to date have described the diet requirements of young humpback chub either in the mainstem Colorado River or in the Little Colorado River.

Stable isotopes of carbon, nitrogen and other elements have been cited as good tools for identifying the source of energy in food webs (Rosenfield and Poff 1992, Barrie and Prosser 1993, Parker et al. 1993 and Schell and Ziemann 1993). Dietary studies based on stomach content and volume are biased by variable rates of digestion for specific food items (Barrie and Prosser 1993, and Parker et al. 1993). These studies may exaggerate the importance of food items that are large and easy to count in gut contents or have indigestible body parts. Small food items that are quickly digested may not appear in gut content analysis although their overall contribution to the diet of the study organisms may be great. Stable isotope analysis eliminates these types of biases by measuring the isotopic signal of the tissue of the study organism; measuring only the signal of food items that have actually been assimilated into the organism. These signals then can be tracked back to the available food items in the system to show the relative importance of specific energy sources (Angradi 1994).

This project has two main objectives. The first is to estimate the standing crop and seasonal availability of the aquatic benthos in this system, which is the likely source of energy for the system. The second is to describe the food resources of the humpback chub in the LCR using stable isotope techniques. Information from this research will be used to develop understanding of the Little Colorado River ecosystem and the resources that it provides to the resident and transient humpback chub population. An understanding of these resources will help managers to better understand the ecology of native fishes that depend on the Little Colorado River for portions of their life history. In addition, the stable isotope analysis of the diet of humpback chub found in the Little Colorado River will be incorporated into a stable isotope project being conducted by the Northern Arizona University Colorado River Food Base monitoring lab. The objectives of this project are to describe a food web for the greater Grand Canyon Ecosystem. Methods developed during this project for non-lethal sampling of stable isotopes in endangered fishes will be employed in future monitoring and research of these fishes.

Methods

The benthos and aquatic drift of the Little Colorado River were sampled at two different sites (Fig. 1). The first site is above the Atomizer/Chute Falls complex at river kilometer 14.5. This site has low densities of humpback chub either due to high concentrations of dissolved CO₂ or because the falls act as a physical barrier to upstream migration. The small bodied speckled dace and fathead minnow are the only fish consistently caught in this area. The second site in the Little Colorado River is located at river kilometer 10.5 near Salt Canyon. This site has high densities of humpback chub and other fish. Dissolved CO₂ concentrations are often substantially lower in this area compared to the previous site. By comparing benthic standing mass and drift of the two sites, comparisons can be made as to the effect of CO₂ level and possibly the effect of fish density on aquatic benthos. One other site in Salt Creek, a tributary of the Little Colorado River was sampled. This site was chosen to provide information on the influence that the many springhead systems may have on the aquatic food base. Because these springs are not subject to high levels of suspended sediments on a regular basis they may provide a source for recolonization of the Little Colorado River after high flows. Springs may also directly contribute food to fish within the Little Colorado River as drift.

Hard benthic substrates were sampled using a Surber sampler. Six samples were taken at each site (3 in Salt Creek). Substrates were scraped for 30 s with a metal trowel to remove benthos. Depth and water velocities were recorded for each sample. Soft sediments in the Little Colorado River were sampled using a petite Ponar dredge. Six samples were collected along two transects running perpendicular to the shoreline. The three samples at each transect were taken with increasing distance from the shoreline to the thalweg. Depth and relative distance from shore were recorded for each sample. Additional invertebrate samples from soft and hard sediments were taken for taxonomic purposes.

Both fine particulate organic matter (FPOM) and coarse particulate organic matter (CPOM) drift were sampled. Both collections were made in triplicate at surface level. CPOM was collected in a rectangular 0.14 m² 0.5 mm mesh net. FPOM was collected in a 0.3 m diameter net with a 153 µm mesh. FPOM in Salt Creek tributary was collected with a 0.14 m diameter net with a 153

μm mesh because of the shallow depths at this site. Velocity for each sample was collected with a Marsh-McBirney electronic flow meter.

All CPOM and benthic samples were sorted live within 48 hrs of collection. Samples were sorted into 10 different categories including: annelid worms, tubificid worms (oligochaetes), simuliids, chironomids, gastropods, miscellaneous macroinvertebrates, *Cladophora glomerata*, cyanobacterial crust, detritus and miscellaneous algae, macrophytes and bryophytes. Samples were dried and weighed then converted to ash-free-dry-mass using regression equations.

FPOM samples were stored in 70% ETOH and sorted in the laboratory using a dissecting scope. Samples were sorted into the following categories: Copepoda, Cladocera, Ostracoda, miscellaneous invertebrates and detritus. Samples of invertebrates were dried and weighed then converted to ash-free-dry-mass using regression equations. Detrital ash-free-dry-mass was determined by combustion for 1h at 500°C.

Selected water quality parameters were measured to characterize each sampling site. Dissolved oxygen (mg/l) and temperature (°C) were determined using a YSI handheld DO meter. CO₂ was measured using a HACH field titration kit or a handheld CO₂ meter. Water samples were collected and stored on ice for determination of total alkalinity (mg CaCO₃ by titration), specific conductance (μmho), turbidity (NTU), pH, and suspended particulate matter (mg/l) in the laboratory.

Stable isotope samples were dried in the field and the lab. Each sample was ground to a fine powder with a Whirl-a-bug amalgam shaker, weighed and sent to Institute of Ecology, University of Georgia, Athens for analysis.

Statistical analysis for benthic data was analyzed using natural logarithm transformed data to improve homoscedascity. Specific patterns were detected using MANOVA techniques in Systat 5.2.1 for the Macintosh (Systat, Inc. 1992).

Results

The data in this report are preliminary dry-mass estimates of benthic standing crop. Final analysis will be based on ash free dry-mass estimates. These data represent two collecting trips in the Little Colorado River during 1998. A preliminary trip was made for stable isotope collections and selection of sites for benthic collections. Preliminary analysis were made in an effort to show trends detected during the first months of this project and may change as sampling effort is extended through more seasons and hydrologic conditions.

Water Quality.-Specific conductance and CO₂ concentrations were high at benthic collection sites in the Little Colorado River during base flow in June 1998 (Table 11). Both parameters were diluted by high flows from storm runoff in August 1998. Specific conductance decreased to 2.719 μ S and 3.078 μ S at Chute Falls and Salt Canyon sites respectively during runoff, while CO₂ concentrations decreased to 38.71 mg/L at Salt Canyon during storm runoff. Secchi depth also decreased at both sites to <1 cm during high flow.

Salt Creek water quality parameters were unaffected by high flows originating high in the Little Colorado River basin. Specific conductance of Salt Creek was generally higher than sites in the Little Colorado River while CO₂ concentrations were generally lower than at the Chute Falls site in the Little Colorado River during base flow conditions (Table 11).

Benthic Standing Mass Estimates and composition.-Preliminary multivariate analysis of variance of dry weights for specific biotic categories showed significant responses by trip and site (Table 12). Chute Falls site had the highest mass of cyanobacterial crust (*Oscillatoria* spp.) with 264.9 g/m² dry weight (SE = 66.3) during base flow in June 1998. Dry mass of cyanobacterial crust declined during high flows in August 1998. Benthic detritus increased during high flows in August 1998; however, this increase is probably a sampling artifact since drifting detritus was captured by the open net of the Surber sampler. Miscellaneous algae and macrophytes (MAMB) had the highest mass in the Salt Creek site during June 1998 (44.96 g.m⁻² dry weight, SE = 9.7). Dry mass of benthic macroinvertebrates declined in August 1998. The highest dry mass estimates of macroinvertebrates was at the Chute Falls site in June 1998 (0.214 g.m⁻² dry weight, SE = 0.055).

The benthic macroinvertebrate communities on hard substrate at sampling sites in the Little Colorado River were dominated by chironomids and a caseless caddisfly during June and August sampling trips. Occasionally, mayflies and commonly terrestrial invertebrates make up a portion of the standing mass on hard substrates. The terrestrial insects presumably are entrained in the drift and captured in the open net of the Surber sampler. The benthic algae are dominated by the cyanobacteria *Oscillatoria* spp. at sites in the Little Colorado River. The filamentous green alga *Cladophora* spp. was rare or not found at sampling sites in the Little Colorado River canyon. Soft substrates contained chironomids and a burrowing odonate (Anisoptera).

Composition of the benthic community in Salt Creek is different from the Little Colorado River. The benthic algae were mostly the chain forming, halophillic diatom, *Biddulphia* sp. The macroinvertebrate community consisted mostly of chironomids and a damselfly (Zygoptera). As in the Little Colorado River, terrestrial insects comprised a substantial portion of the benthic standing mass.

Drift mass estimates and composition.-Detritus and miscellaneous algae and macrophytes were the only variables tested that showed significant variation by trip or site (Table 13) for CPOM drift. Miscellaneous algae and macrophytes in drift samples were highest at the Salt Creek tributary site during both trips in 1998. Detritus mass was highest at the Chute Falls site during August 1998, reflecting entrainment during peak runoff. The mass of invertebrates in the CPOM drift was highest at the Chute Falls during August 1998 (0.0022 g.m⁻³ dry weight, SE = 0.0022) and did not vary significantly by trip date or site (Table 13). FPOM drift samples are currently being sorted and weighed for future analysis.

Stable Isotope analysis of humpback chub diet.-Samples of algae (*Oscillatoria*, *Cladophora*, *Biddulphia*) and benthic and terrestrial invertebrates in the Little Colorado River have been collected on each sampling trip. These samples represent food items that our surveys indicate may be available for higher trophic levels. Tissue samples have been collected from humpback chub and other fish from the Little Colorado River as well as the mainstem Colorado River and other tributaries thanks to the efforts of USFWS personnel. Due to opportunistic sampling of

other native/nonnative fish in the Little Colorado River and other areas of the Grand Canyon ecosystem, we currently have more samples for analysis than originally planned. We plan to take advantage of these samples by expanding our analysis pending funding in FY99. All samples are currently being processed for shipment and mass spectrometer processing.

Table 11. Water quality parameters for Chute Falls (RKM 14.7), Salt Camp (RKM 10.1) and Salt Creek tributary sites in the Little Colorado River canyon for June 1998 collecting trip.

Site	Chute Falls	Salt Camp	Salt Creek (trib)
Date	6/6/98	6/7/98	6/7/98
Time	1430	1600	1715
Flow (m ³ /s)	6.5	6.5	0.06
DO (mg/L)	8.21	7.49	5.95
PH	6.9	7.1	6.0
Secchi (m)	>2.5	1.1	>0.5
Turbidity (NTU)	1.29	9.84	1.41
CO ₂ (mg/L)	237.00, SE = 1.76, N = 3	141.25, SE = 2.21, N = 4	173.00, SE = 12.73, N = 4

Table 12. Results of multiple analysis of variance (MANOVA) for benthic dry mass on hard substrates at sites in the Little Colorado River during collection trips in June and August 1998. The predictor variables trip date and site were analyzed with respect to response variables of dry weight (g.m⁻²) for (C) Cladophora, (D) detritus, (O) Oscillatoria crust, (G) miscellaneous green algae and macrophytes, and (M) macroinvertebrates on ln+1 transformed data. Overall Wilks' lambda was significant ($p < 0.00001$). Only significant univariate response variables are listed ($p < 0.04$).

Source	Wilks' lambda	Approximate F-statistic	Degrees of freedom	P	Response variable
Site	0.036	16.9	1040	<0.0001	D,O,G
Trip	0.116	30.3	520	<0.0001	D,O,G,M
Site*Trip	0.120	7.5	1040	<0.0001	D,O

Table 13. Results of multiple analysis of variance (MANOVA) for CPOM dry mass in drift samples at sites in the Little Colorado River during collection trips in June and August 1998. The predictor variables trip date and site were analyzed with respect to response variables of dry weight (g.m⁻³) for (C) Cladophora, (D) detritus, (G) miscellaneous green algae and macrophytes, and (M) macroinvertebrates on ln+1 transformed data. Overall Wilks' lambda was significant ($p < 0.00001$). Only significant univariate response variables are listed ($p < 0.04$).

Source	Wilks' lambda	Approximate F-statistic	Degrees of freedom	P	Response variable
Site	0.005	27.1	818	<0.0001	D,G
Trip	0.024	88.7	49	<0.0001	D,G
Site*Trip	0.006	26.5	818	<0.0001	D,G

Status of Data Integration and Analysis

A lack of staff and funds prior to delayed finalization of the contract slowed progress on data integration/analysis throughout most of FY1998. The field season commenced 27 March and more than 65 days were spent in the field by the staff prior to 12 September 1998. New project personnel were added to the Grand Canyon Fishery Resource Office staff during June, 1998. Data entry for FY1998 field data commenced on 15 April and is projected to be complete by 1 December 1998. An integrated database for LCR spring native fish monitoring for the period 1978-1996 was completed by 1 February 1998 and will be updated through the 1998 field season by 1 December 1998.

Projection for FY99 Monitoring and Studies

Table 14. Provisional fieldwork schedule for fiscal year 1999.

Trip title	Dates	Trip objective
Little Colorado River food base monitoring	3-6 December 1998	Macroinvertebrate, stable isotope studies
Little Colorado River monitoring and research	26 March-5 April 1999	Fishery research and monitoring
Little Colorado River monitoring and research	27 April-7 May 1999	Fishery research and monitoring
Little Colorado River food base monitoring	25-28 May 1999	Macroinvertebrate, stable isotope studies
Mainstem Colorado River and tributaries monitoring and research	16 June-1 July 1999	Fishery research and monitoring
Little Colorado River monitoring and research	21-30 July 1999	Fishery research and monitoring
Mainstem Colorado River and tributaries monitoring and research	15 September-1 October 1999	Fishery research and monitoring
Little Colorado River food base monitoring	27-30 September 1999	Macroinvertebrate, stable isotope studies

Other Activities

Lower Colorado River Workshop: 8-9 July, UNLV-Las Vegas

Grand Canyon Modeling Workshops: 20-22 May, 6-7 July, 23-24 October

Participating Personnel and Institutions

U. S. Fish and Wildlife Service, Grand Canyon Fishery Resources Office, primary contract holders.

Project Leader	Owen T. Gorman
Assistant Project Leader	Robert G. Bramblett
Project Biologist	David R. Van Haverbeke
Project Biologist	Richard Van Hoosen
Assistant Project Biologist	Dennis M. Stone
Fish Health Biologist	Jerry Landye
Intra-agency participant	Cliff Schluesner
Intra-agency participant	Cynthia Martinez
Volunteer	Edward Woods
Volunteer	Virgil Frye
Volunteer	Bobbi Hervin
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